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A FURTHER EXAMINATION OF OPERATIONAL AVAILABILITY IN LIFE CYCLE COST MODELS

Thesis

Fredrick C. Farnell, Captain, USAF

AFIT/GLM/LSM/84S-19

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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A FURTHER EXAMINATION OF OPERATIONAL AVAILABILITY IN LIFE CYCLE COST MODELS

THESIS

Presented to the Faculty of the School of Systems and Logistics

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Master of Science in Logistics Management

Fredrick C. Farnell, B.S.

Captain, USAF

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Preface

The purpose of this study was to develop a derivative of the Cost Oriented Resource Estimating (CORE) life cycle cost model that calculates operational availability in addition to costs. The availability output acts as a measurable surrogate for supportability and facilitates comparison of alternative weapon system designs.

The impetus for developing a modified model stems from a general difficulty in evaluating supportability in new weapon systems. We understand performance, cost, and schedule and we can measure those things fairly well. Supportability, on the other hand, is not as well understood, nor is it easily measured in the early stages of system development.

My appreciation and thanks to my advisor, Lt Col John Long and reader Mr. Roy Wood. They were helpful, patient, and made this experience interesting and satisfying. I also found the advice and assistance of Don Breidenbach and Lt Danielle Rodgers of the Life Cycle Cost Management Division, HQ ASD to be crucial to the development of the methodology.

Fredrick C. Farnell

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Abstract

In recent years, interest in weapon system supportability has grown tremendously. Coupled with this is a complementary emphasis on life cycle cost analysis. Both arise from a concern that weapon system ownership costs are extraordinarily high and that improved understanding of supportability issues and their effect on life cycle costs can result not only in dollar savings, but also in increased system readiness and capability. These considerations led to development of a methodology for comparing ownership costs and supportability that enables Program Managers to more easily evaluate design tradeoffs. The methodology involves use of a modified life cycle cost model that yields as outputs both relative cost and supportability, where operational availability acts as a measurable surrogate for supportability. The modified model uses the DOD's CAIG approved cost element structures in an attempt to use cost/availability output in support of Defense Systems Aquisition Review Council (DSARC) milestones. The methodology is applied to a sample data base from the HH-60D program.

A FURTHER EXAMINATION OF OPERATIONAL AVAILABILITY IN LIFE CYCLE COST MODELS

I. Introduction

Overview

In recent years, interest in weapon system supportability has grown tremendously. Coupled with this is the complementary emphasis on life cycle cost analysis. Both arise from a concern that weapon system ownership costs are extraordinarily high and that improved understanding of supportability issues and their effect on life cycle costs can result not only in dollar savings, but in increased system readiness and capability as well.

This thesis is an extension of an earlier effort by Captain Thurman Gardner entitled *An [illegible]mination Of Operational Availability In Life Cycle Cost Models*. In it, the author demonstrated that operational availability measures can be used as a surrogate for supportability (in that if the system is available, then it is supported) and that operational availability could be incorporated into the Logistics Support Cost (LSC) Model to give comparative availability and dollar costs as outputs. He reasoned that this kind of information would permit a program manager to better weigh supportability and cost issues during the weapon system acquisition process. This effort will attempt to further validate the use of operational availability as a supportability surrogate, and will apply availability to a model that, unlike the LSC variety, uses the DOD Cost Analysis Improvement Group (CAIG) approved cost element structures. The model to be used is one rejected by Gardner as difficult to modify; the USAF Cost Oriented Resource Estimating (CORE) Model.

How does availability relate to supportability and the acquisition process?

Operational availability in wartime is a necessary requirement if the United States Air Force is to successfully project airpower in support of national objectives. Not heeding this principle can have unfortunate consequences. The Korean Conflict provides the following example:

> Initial Provisioning for the F-86 was based on peacetime consumption rates. Hence, the 51st Wing's unprogrammed conversion to F-86E's severely strained logistical support. By January 1952, 45 percent of the war committed F-86A and E fighters were out of commission for want of parts or maintenance. Theater supplies of external fuel tanks, without which the range limited F-86's were badly handicapped, also were nearly exhausted. "Peter Rabbit," a crash project for buying a 1 year supply of all urgently needed items, solved most of these problems, but it took several months [12:58].

By no means were Korean based F-86's in 1952 a unique problem. As the decade of the 80's started, similar incommission rates were experienced by peacetime fighter units stationed in the United States. Supportability problems like these repeatedly arise, not because the Air Force fails to learn from history, but because, during the weapon system acquisition process, performance and supportability criteria must be weighed against constrained and uncertain funding.

Unfortunately, as the process goes on, supportability criteria often "lose out" in the budget fight with performance because of uncertainty about supportability: what it means, how much is enough, and how much it really costs. Understandably, program managers have difficulty balancing life cycle costs and supportability against the requirement to produce a capable system within time and budget constraints. As a result, support equipment, manpower, spare parts, and a host of other logistics elements can fail to get the attention and funding they deserve. Ultimately, underfunded operations and support factors can drive downstream costs for the deployed weapon system beyond planned levels. The resulting dollar costs are enormous, but costs are also felt in terms of overstretched manpower and low operational availability.

System readiness is not driven by support factors alone, for design factors also apply. If low levels of reliability and/or maintainability are designed in, they cannot necessarily be compensated for with more tools, higher manpower levels, or more money. As Northrup's chairman and chief executive officer recently noted,

> ...too many of our current weapon systems require extraordinarily costly logistics support, and even with such support they still are not capable of sustaining their performance during an intense or prolonged conflict [11:13].

Underfunding those acquisition activities that preclude these design problems can also drive downstream costs. The program manager then must concern himself with injecting capability into the system's logistic support structure and, thus, optimizing a supportable design while at the same time minimizing life cycle costs. He can succeed only through appropriate design tradeoffs, but, again, uncertain visibility with regard to supportability requirements in the life cycle costing process can render affordable supported systems an elusive goal indeed.

The problem, stated briefly, is to find a way to reduce uncertainty in cost/supportability tradeoffs. A current weakness in life cycle cost analysis is the difficulty of realistically evaluating supportability. If supportability can be soundly defined and quantified in a way that takes into account the many factors that can plague deployed operations, then uncertainty in cost/supportability tradeoffs should decrease. The PM will better understand how much supportability he or she is getting and what it will cost.

Definitions

Defining supportability is not easy. DOD Directive 5000.39 defines it as follows:

> Supportability: The degree to which system design characteristics and planned logistics resources, including manpower, meet system peacetime readiness and wartime utilization requirements [23:2-2].

DOD Directive 5000.39 also defines the system readiness objective in terms of, among other things, operational availability.

> System Readiness Objective: A criterion for assessing the ability of a system to undertake and sustain a specified set of missions at planned peacetime and wartime utilization rates. System readiness measures take explicit account of the effects of system design R&M, the characteristics and performance of the support system, and the quantity and location of support resources. Examples of system readiness are combat sortie rate over time, peacetime mission capable rate, operational availability, and asset ready rate [23:2-3].

A useful reference was provided recently by Mohr and Corner [16:33] who acknowledged cost constraints while stating: "Supportability is synonymous with economically sustainable usability. A weapon system is supportable to the extent that it's operational use can be sustained at an affordable cost." Mohr and Corner distinguish between what is theoretically achievable and what is economically sustainable. They point out that acquisition strategy often focuses on the theoretically achievable while it fails to cross the bridge to practical requirements (economic sustainability). "It is not theoretical power, but practical (useable) power that counts. To be effective, weapons systems must be kept useable - must be kept operational [16:33]." Mohr and Corner look to the various availability measures as the key to reaching beyond theoretically achievable and achieving economically sustainable, or supportable, weapon systems. This kind of reasoning leads one to conclude that a close relationship between supportability and availability may be reasonably inferred.

From the Compendium of Authenticated Systems and Logistics Terms, Definitions and Acronyms [17:81], comes the following definition:

> Availability is a measure of the degree to which an item is in the operable and commitable state at the start of the mission when the mission is called for at an unknown (random) time (inherent availability) (MIL-STD-721B/AR 705-50). For OT&E purposes, availability is considered synonymous with operational readiness. (AFR 80-14/AFP 800-7)

Blanchard [4:66] describes three treatments of availability.

1. Inherent Availability:

$$A_i = \frac{MTBF}{MTBF + MTTR} \qquad (1)$$

Where

A_i	is inherent availability
MTBF	is mean time between failures
MTTR	is mean time to repair

MTBF accounts for failures for which a contractor could be held legally accountable. MTTR includes only those unscheduled maintenance actions, or direct, active maintenance time, needed to restore the failed item to operational status. Not included is logistics delay time. Scheduled maintenance tasks are also not included.

2. Achieved Availability:

$$A_a = \frac{MTBM}{MTBM + M} \qquad (2)$$

Where

A_a	is achieved availability
MTBM	is mean time between maintenance
M	is mean active maintenance time

MTBM includes preventative (scheduled) maintenance and failures (unscheduled) maintenance. M accounts for both types of maintenance actions. Again, logistics delay time is not included.

These two terms, inherent and achievable availability are objectively measureable, contractually enforceable, and are expressions of the "theoretically achievable" that are used when dealing with contractors [16:34].

Unfortunatcly, these term's Achilles heel is the failure to include logistics delay time. This factor accounts for supply delays, work stoppages for lack of manpower, tools, facilities, POL, and any other of a myriad of factors that cause systems to remain inoperative when they shouldn't be. In order to achieve the "economically sustainable" then, we must look at another definition of availability.

3. Operational Availability:

$$A_o = \frac{MTBM}{MTBM + MDT} \qquad (3)$$

Where

A_o	is operational availability
MDT	is mean maintenance downtime
MTBM	is mean time between maintenance

MDT is the factor that includes the less-than-ideal aspects of the real world logistics environment. This equation does not assume an abundance of tools, spares, and manpower. It forces consideration of those issues and highlights the impact of shortages.

If operational availability measures the "sustainable" in "economically sustainable" then measurement of the "economical" is done through life cycle costing. Air Force Regulation 800-11 defines life cycle cost as

> "the total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership (operation, maintenance, support, ect.), and, where applicable, disposal" [19:1].

The LCC approach to costing came out of rising concerns during the 1970's that ownership costs were, in some cases, far in excess of development and acquisition costs. (See Figure 1.) Clearly these costs had to be brought under control. While earlier concepts within the design to cost framework focused on development and acquisition costs, LCC went further and allowed program managers to consider downstream operations and support costs as well. AFR 800-11 also defines the purpose of LCC: "The use of life cycle cost is not intended to make minimum cost the predominant factor, but to insure a proper balance between cost and system effectiveness [19:2]."

Background

The Air Force Acquisition Process. The backdrop for this discussion is the acquisition process itself. Briefly

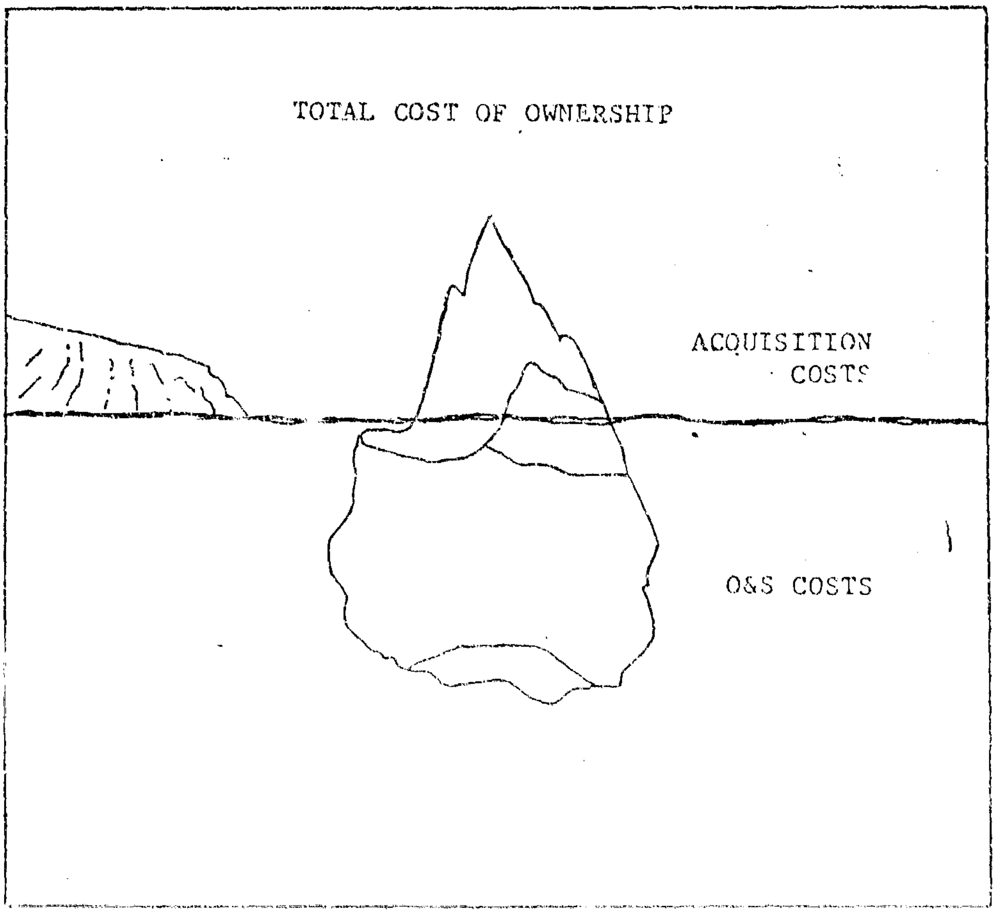

Fig. 1. Total Cost of Ownership

the process consists of four phases: concept exploration, demonstration and validation, full scale development, and production and deployment. (See Figure 2.)

The concept exploration phase begins with a need developed during the requirements determination process. This need, articulated in a justification for major system new start (JSMNS), goes to the Secretary of Defense, who issues guidance through the Program Decision Memorandum (PMD) and who authorizes the acquisition community to proceed.

During the concept exploration phase, initial studies are conducted to determine operations and maintenance concepts, costs, schedule, readiness objectives, and affordability. These items are included in the system concept paper (SCP) and are evaluated at Milestone I by the Defense Systems Acquisition Review Council (DSARC). A decision to proceed at Milestone I authorizes the Air Force to enter the demonstration and validation phase. Now the system is further defined through testing and study until Milestone II.

If there is a decision to proceed, then the full scale development phase begins. The System prototype is built and tested. (In some cases, full scale development is started

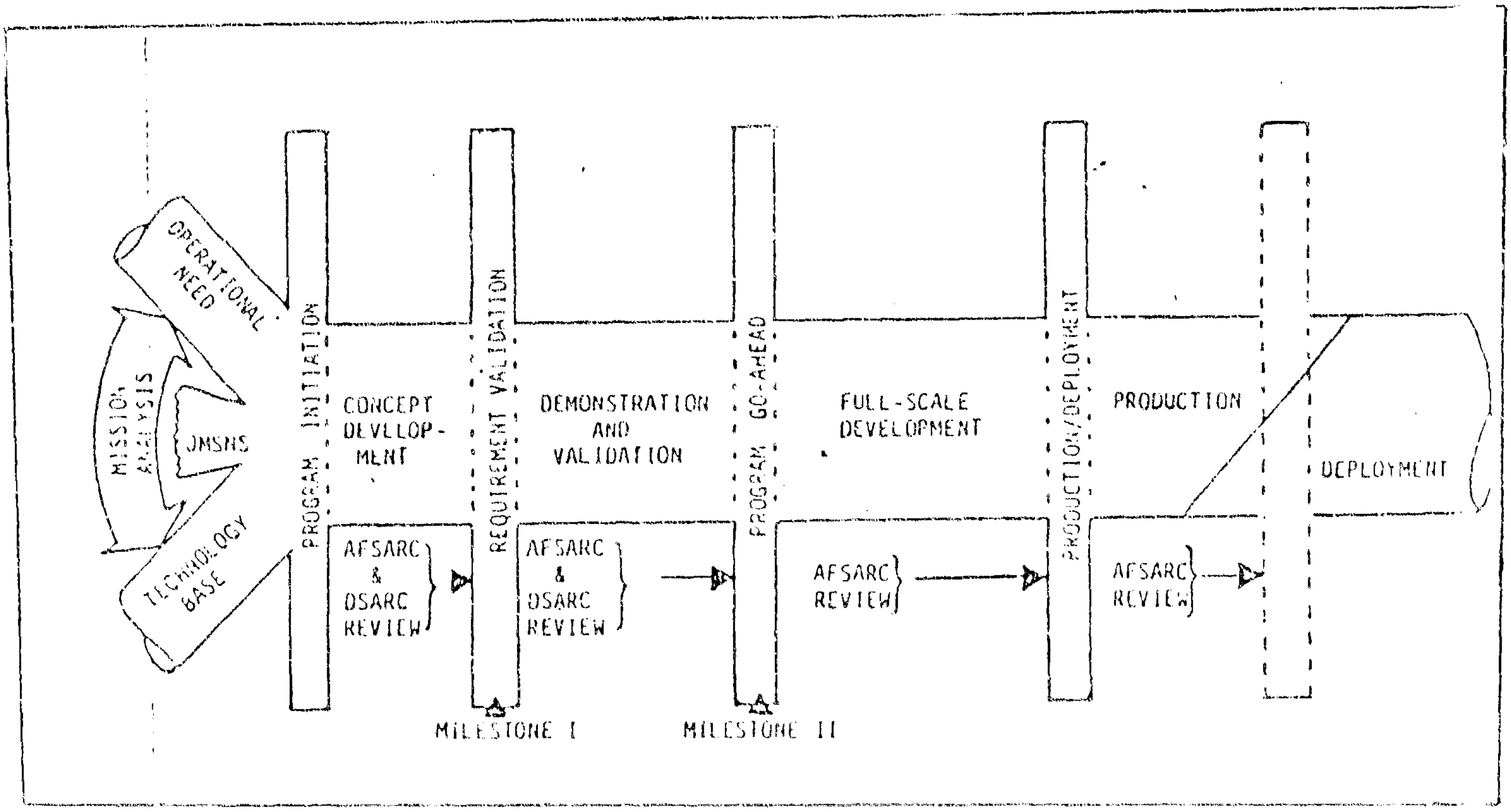

Fig. 2. Major Weapon System Acquisition Process

before Milestone II. The intention in such cases is to better define acquisition objectives before major resource application increases occur.) By the end of the full scale development phase the system is ready for production and deployment. If design and cost thresholds have not been exceeded, then the deployment can proceed based on the Milestone III decision of the Air Force Systems Acquisition Review Council.

Literature Review. Guidance on the use of cost analysis is found in DODI 5000.2. It requires that cost information be submitted to the DSARC for use in their decision making:

> Cost effectiveness analysis for all major acquisitions shall be performed by the DOD components to support milestone I and milestone II, and shall be provided to the Director, Program Analysis and Evaluations, along with the draft SCP ... [22:5].

DODD 5000.1 also addresses the issue of life cycle cost planning and it's relation to operational effectiveness:

> A cost effective balance must be achieved among acquisition costs, ownership costs of major systems, and system effectiveness in terms of the mission to be performed [21:3].

DOD Directive 5000.1 describes some other basic goals of the acquisition process:

> Improved readiness and sustainability are primary objectives of the acquisition process. Resources to

> achieve readiness will receive the same emphasis as those required to achieve schedule or performance objectives. As a management precept, operational sustainability of deployed weapon systems is an objective of equal importance with operational effectiveness [21:2].

Clearly, the emphasis on the readiness objective moves supportability issues to the upper end of the program manager's list of priorities. In the past, program managers were evaluated on their ability to meet performance and schedule objectives while developing new weapon systems. As costs rose, more and more visibility was given to ways to control acquisition costs and keep systems affordable. Today's fiscal constraints force the acquisition community to protect funding for readiness and support of new systems and to seek ways to control downstream operations and support costs (synonymous with ownership costs) through the consideration of life cycle cost. Expensive weapons simply cannot be procured in large enough numbers to allow some to sit around in an unserviceable state. Support and readiness affordability issues then, must be addressed and are prominent in the pages of DODD 5000.1.

If operational availability can be combined with a life cycle cost model, then a program manager should find the resulting output data useful in assessing the future readiness of his system.

Gardner's earlier effort examined several life cycle cost models to see if any could be modified to give operational availability as an output. Some clearly could not be modified because the models could not accept input data to match any availability equation. Others were considered workable and Gardner finally settled on the Logistic Support Cost (LSC) Model as the easiest and most straightforward.

While he succeeded in showing that operational availability can be a useful term in analyzing cost and design tradeoffs, the LSC Model has a significant shortcoming in that it does not use the approved cost element structure for aircraft put out by the Cost Analysis Improvement Group (CAIG) in 1980 (Table I). The cost element structure was standardized in an attempt to deal with the issue of comparability in life cycle costing. Decision making is difficult when various models use different kinds of data and generate output that cannot be easily compared. As a result, the LSC Model is not really as useable (as is the Cost Oriented Resource Estimating Model for example) in any attempt to reduce uncertainty further through the use of operational availability because it's output cannot be used in the DSARC process.

Gardner rejected the CORE Model as difficult to work with, but considered it useable. However, this effort will concentrate on the CORE Model, because it uses the approved

Table I

Operating and Support Cost Elements (Aircraft) [2:9]

OPERATING AND SUPPORT COST

- UNIT MISSION PERSONNEL
  - Aircrew
    - Military
  - Maintenance
    - Military
    - Civilian
  - Other Unit Personnel
    - Military
    - Civilian
- UNIT LEVEL CONSUMPTION
  - Petroleum, Oil, & Lubricants
  - Maintenance Material
  - Training Ordnance
- DEPOT LEVEL MAINTENANCE
  - Airframe Rework
  - Engine Rework
  - Component Repair
  - Support Equipment
  - Software
  - Modifications
  - Other Depot
  - Contracted Unit Level Support
- SUSTAINING INVESTMENT
  - Replenishment Spares
  - Replacement Support Equipment
  - Modification Kits
  - Other Recurring Investment
- INDIRECT PERSONNEL SUPPORT
  - Miscellaneous Operations and Maintenance
  - Medical O&M Non-Pay
  - Permanent Change of Station
  - Temporary Additional Duty Pay
- DEPOT NON-MAINTENANCE
  - General Depot
  - Second Destination Transportation
- PERSONNEL ACQUISITION AND TRAINING
  - Acquisition
  - Individual Training
- INSTALLATION SUPPORT PERSONNEL
  - Base Operating Support
    - Military
    - Civilian
  - Real Property Maintenance
    - Military
    - Civilian
  - Medical
    - Military
    - Civilian

aircraft cost element structure, to further validate the utility of operational availability in reducing uncertainty in LCC analysis.

Research Questions

1. Is operational availability a suitable surrogate for supportability when used in LCC analysis?

2. Can a life cycle cost model that uses the CAIG approved cost element structure be modified to give cost versus operational availability as an output?

Research Objective

The research objective is to examine how operational availability, representing supportability, can be incorporated into a suitable life cycle cost model in order to provide useful comparison data to the program manager. The overall purpose of such output data is to improve the visibility of supportability issues in the decision making process.

II. Methodology

This chapter provides an overview of the specific steps taken in this project to solve the research problem. These steps were designed with the intent of reaching a correct, sound conclusion.

Orientation to Subject Matter

The first step, as in any research project, was to gain an appreciation of the subject at hand. This was accomplished through a systematic review of various sources of literature to include general articles, DOD publications, textbooks and unpublished research manuscripts. Because this project is a follow on to LSSR 57-83, "An Examination of Operational Availability in Life Cycle Cost Models," the orientation process was greatly simplified.

In that earlier effort, the author had sought an increased understanding of the major components of his research, availability and life cycle costing. In addition, this author brought in a third term, supportability, in order to strengthen understanding of the link between it and availability. This satisfied the first research question.

Model Analysis

The second step of this research was to identify the shortcomings of the Logistic Support Cost (LSC) model and select another model that met applicability criteria and overcame the LSC models shortcomings. The objective of this analysis was much like Gardner's: "...to find a model that could specifically address availability and evaluate the impact of design changes with respect to system availability and costs [7:15]".

In his analysis, Gardner [7:15] listed three major areas of concentration in his applicability criteria:

1. Which of the phases of a system's life is the model directed at?
2. Does the model evaluate, estimate, or use availability and/or R&M parameters?
3. Can the model be adapted to evaluate availability?

There were five models considered by Gardner (Table II). Those same five were briefly considered again here, but one more criterion was evaluated:

4. Does the model use the CAIG approved cost element structure?

As stated before, the LSC model does not meet this last condition. In fact, of the five, only the CORE model does.

Table II

The LCC Models Surveyed by Gardner [7:14]

---

1. Cost-Oriented Resource Estimation (CORE).
2. Development and Production Costs of Aircraft (DAPCA).
3. Logistic Support Cost (LSC).
4. Logistics Composite (LCOM).
5. Programmed Review of Information for Costing and Evaluation (PRICE).

Gardner also noted that the CORE model would be difficult to adapt to meet this objective. Help came in the form of another model that had not yet been released for general use. The Initial Support Investment And Operating And Support (O&S) Cost Model (also known to its developers as CORE F) brought with it two qualities that eased CORE adaptation considerably. It uses the same basic variable structure as LSC, and it uses the CAIG approved cost element structures. As a result, the CORE F model meets all of the applicability criteria listed in both Gardner's research effort and this one. Moreover, its outputs constitute some of the input factors for CORE itself. Hence, CORE F provides a convenient bridge between LSC and CORE.

Applications Analysis

The third step was to take the selected model (in this case the CORE F model) and modify it to give cost versus operational availability as an output. This would begin to satisfy the second research question.

Modification of the CORE F model required several actions. Selected cost elements had to be built into new algorithms to incorporate operational availability into the model. Both the selected cost elements and later, the algorithms were checked with LCC analysts to confirm validity. Test data was gathered and run through the algorithms as a further check and then adjustments were made as they became necessary. The ground rules that Gardner used to select the data were good ones and so much of the same data base was used again here (Table III).

Table III

Data Selection Criteria

---

1. Selection of data from combat systems was stressed because their readiness or availability was assumed to be more critical than non combat systems.

2. The data selected was from the subsystem level rather than from the entire system (or end item) level in order to simplify the computations while still accomplishing the research objective.

3. R&M data was expressed in operational terms whenever possible since operational values include the combined effects of several real world operational factors.

Finally, a demonstration run was made of the modified CORE F model using the data used in the modified LSC analysis. This demonstration was not intended to second guess decisions made in any program, but to show that the modified model is useful. Drawing any "real world" conlusions from these computations is risky in any case because of some data base limitations that are further explained in Chapter 4.

Implications and Conclusions

Modifying the CORE F model and using it and the information and data collected in a sample application answered the research questions and met the objective. Based on the implications and conclusions, areas for further research were identified.

III. Model Analysis

Modifying The Models

In his earlier effort, Gardner addressed the issue of incorporating operational availability into the LSC model. He took reliability and maintainability factors from the existing LSC input list and applied them to the following equation for operational availability [7:26]:

$$A_o = \frac{OT+ST}{OT+ST+TPM+TCM+ALDT} \tag{4}$$

where

OT	is operational time
ST	is standby time
TPM	is total preventative maintenance time
TCM	is total corrective maintenance time
ALDT	is average logistics delay time

Remembering Blanchard's equation given in Chapter 1, note that

$$MTBM = OT + ST \tag{5}$$

and

$$MDT = TPM + TCM + ALDT. \tag{6}$$

The author took the availability output from this equation and merged it with the LSC cost figures to come up with a new measure for competing components. Instead of measuring the difference in costs (Δc) for different components, the new measure was the change in availability per change in cost (or $\Delta Ao/\Delta c$) [5]. The program managers who use this kind of information could now make informed judgements regarding the tradeoffs between cost and supportability [7:51].

Of course the LSC model's limitations, as mentioned earlier, do not allow use at DSARC milestone decisions. The obvious solution to this problem is to similarly modify the CORE analysis to include operational availability. Unfortunately the CORE input factors don't readily fit the equation for operational availability. The input list for the CORE model has to be expanded.

Part of the solution lies in a new LCC model developed recently by cost analysis experts at Aeronautical Systems Division [5]. Called CORE F, this model takes component level outputs from LSC and converts them by means of CERs to yearly system level inputs for CORE. An expanded input variable list will allow a modified CORE F model to do the same cost versus operational availability analysis as the modified LSC can do now. The advantage gained is that this analysis is done at system level, is year by year, and uses the same CAIG approved cost element structures that higher level managers like those at the DSARC would wish to see.

The Models

In order to place the LSC and CORE models in perspective, a brief overview of LCC models is in order. These models are generally of two types: the large complex simulations like L-COM, and analytical models. Analytical models employ three techniques: analogy (estimates based on "expert opinion"), parametrics, and engineering (a precise approach that requires a detailed data base). Models using parametrics are characterized by the use of cost estimating relationships (CER's). These equations can be either factor based (usually these factors are chosen through common sense or experience) or regression based (derived through a statistical regression method such as least squares) [14].

Timing affects the use of these various model types. Simulations and engineering are generally used in the later acquisition stages because of their need for large quantities of firm data. This data generally becomes available well after the conceptual phase when so many critical decisions are made [14]. Analogy and parametrics, on the other hand, are useable early in the program.

<u>The Logistic Support Cost (LSC) Model</u>. The LSC, or Logistic Support Cost, model is a factor based parametric model that looks at operating and support costs over the life of a system. It sums logistics support costs over eleven areas: [9:24]

1. Initial and replenishment First Line Unit (FLU) spares cost.
2. On-equipment maintenance cost.
3. Off-equipment maintenance cost.
4. Inventory management cost.
5. Support equipment cost.
6. Personnel training cost.
7. Management and technical data cost.
8. Facilities cost.
9. Fuel consumption cost.
10. Spare engines cost.
11. Software cost.

Both inputs and outputs are at the component and subcomponent level. The inputs required are fairly extensive and must be gathered for each component. This model is not generally used for system level analysis since (1) the cost categories it deals with are different from those the DSARC looks at and (2) a typical system has many components on board and the analytical manhours required to do a system level analysis would be exhorbitant [15:4-7].

The Cost Oriented Resource Estimating (CORE) Model. The Cost Oriented Resource Estimating model, like LSC, is a factor based parametric model. It, too, looks at operating and support costs but, unlike LSC, looks at one year at a time rather than over the system's whole life. Also unlike LSC, CORE is a higher level model that uses system level inputs and outputs. It also uses the CAIG approved cost element structures [20:103,2:9]. Costs are calculated for eight areas: [9:1]

1. Unit Mission Personnel
2. Unit Level Consumption
3. Depot Level Maintenance
4. Sustaining Investment
5. Installation Support Personnel
6. Indirect Personnel Support
7. Depot Non-Maintenance
8. Personnel Acquisition and Training

Neither model addresses the balance between cost and availability (or any other measure of system readiness). Both address relative costs only.

CORE F. The Initial Support Investment and Operating and Support (O&S) Cost Model, or Core F, as it is better known, is a methodology and set of ground rules designed to be used independent of the CORE model. However, the outputs generated by CORE F are used as inputs to CORE to compute systems level estimates [10:1]. Input factors are, in most cases, common to the LSC model as well.

Core F computations cover three main areas that are further subdivided as listed in Table IV.

To illustrate the link CORE F provides between the LSC and CORE models, the replenishment spares calculations are provided here with an explanation of terms.

First, the analyst computes the mean demand rate per base ($\lambda_i t_i$) for some first line unit (FLU) or line replaceable unit (LRU).

$$\lambda_i = \frac{(PFFH_K)(QPA_i)}{(M_K)(MTBD_i)} \qquad (7)$$

$$t_i = (RTS_i)(BRCT) + (NRTS_i)(OST) \qquad (8)$$

where

i	is the index identifying each LRU
$PFFH_K$	is peak monthly force flying hours in operational year, k
QPA_i	is the quantity of identical LRUs per application
M_K	is the number of active bases for each operational year, k
$MTBD_i$	is the mean time between demands in flying hours for the ith LRU

Table IV

CORE F Output Factors

---

1. Spares Equations

    Pipeline Spares
    Condemnation Spares
    Training Equipment Spares
    Peculiar Support Equipment Spares
    Replacement Support Equipment Spares
    Update Modifications
    Reprocurement Data

2. Initial Support Investment

    Training Equipment
    Common Support Equipment
    Peculiar Support Equipment
    Initial Spares

3. Operating and Support Costs

    Maintenance Manpower
    Replenishment Spares
    Replacement Support Equipment
    Depot Maintenance
    Software Support
    Second Destination Transportation

RTS_i	is the fraction of the ith LRU removals reperable at the base level
BRCT	is the standard base repair cycle time in months
$NRTS_i$	is the fraction of the ith LRU removals not reparable at base level
OST	is the standard order and shipping time in months

Note that QPA_i, RTS_i, BRCT, $NRTS_i$, and OST are all common input factors for the LSC model. Of the others, M_K and $PFFH_K$ are constants, and $MTBD_i$ is used instead of LSC's MTBF (mean time between failures). (In using MTBD, the model does not consider on-equipment maintenance where no demands are put on the supply system.)

The mean demand rate per base is used to calculate STK_i (the total number of spares, including safety stock for a given base):

$$STK_i = \lambda_i t_i + 1.6\sqrt{\lambda_i t_i} \qquad (9)$$

STK_i, another LSC input factor, is then used to calculate pipeline spares at system level using the following equation:

$$PS_K = \sum_{j=1}^{Y} (F_j) \left[M_K \sum_{i=1}^{N_j} (STK_i)(UC_i) + \sum_{i=1}^{N_j} \frac{(PFFH_K)(QPA_i)(NRTS_i)(DRCT)}{(MTBD_i)} (UC_i) \right] \quad (10)$$

where:

PS_K	is total cumulative pipeline spares cost per operational year, K
N_j	is the number of individual LRUs within the jth 2-digit work unit code (WUC)
UC_i	is the cumulative average unit production cost for the ith LRU
DRCT	is the depot repair cycle time in months
F_j	is the factor used to calculate SRU (shop replaceable unit) pipeline spares dollar requirements for the jth 2-digit WUC
j	is an index identifying each 2-digit WUC
Y	is the number of 2-digit WUCs

PS_K is used to compute the additional pipeline spares cost (APS_K). "APS_K is computed as a series of annual requirements with each year's requirement being the additional (delta) spares cost needed to support the increased number of aircraft and the increased flying hour program associated with weapon system phase-in [10:13].

$$APS_K = PS_K - (PS_{K-1}) \quad (11)$$

APS_K is then used in conjunction with other similarly derived spares factors to calculate replenishment spares cost per operational year (RS_K).

$$RS_K = \sum_{k=1}^{H+1} APSS_K + \sum_{k=3}^{H+1} APSN_K + \sum_{k=1}^{K} CSS_K + \sum_{k=3}^{K} CSN_K + \sum_{k=H+1}^{K} PSES_K$$

$$+ \sum_{k=1}^{K} CSES_K + \sum_{k=H+1}^{H} TES_K + \sum_{k=1}^{K} RPLSES_K \qquad (12)$$

where

$\sum_{k=1}^{n}$	is a notation that identifies for each year, K, the cost elements that are to be added.
H	is the last year of production.
K	is the end of operational life.
1	is the first year of deployment.
k	index for operational year.
$APSS_K$	is the additional pipeline spares cost (APSK) for stock listed "S" items
$APSN_K$	is the additional pipeline spares cost (APSK) for non-stock listed "N" items
CSS_K	is the annual condemnation spares cost for stock listed "S" items
CSN_K	is the annual condemnation spares cost for non-stock listed "N" items
$PSES_K$	is the annual cost of peculiar support equipment spares
$CSES_K$	is the annual cost for common support equipment spares

TES_K is the annual cost for training equipment spares

$RPLSES_K$ is the annual cost for replacement support equipment spares

Replenishment spares cost per flying hour is easily computed as:

$$RSFH_K = \frac{RS_K}{TFFH_K} \qquad (13)$$

where

$TFFH_K$ is the total force flying hours per operational year, K, for all delivered aircraft

$RSFH_K$, or replenishment spares per flying hour, is an input factor for the CORE model and corresponds to F40 in AFR 173-13.

CORE F Variable Combinations

Intuitively, it makes sense that if operational availability can be derived from LSC inputs, then the same should be possible for the CORE model using CORE F variables.

The transform for operational availability, given earlier, is presented again:

$$A_o = \frac{OT + ST}{OT + ST + TPM + TCM + ALDT} \qquad (14)$$

Gardner used LSC variables to derive TPM, TCM, and ALDT. Then he combined them into the following: [7:30]

$$\begin{aligned} A_o = OT + ST/[OT + ST \\ + ((SMH + BCMH + PAMH + BMH)(UR/SMI)) \\ + ((BCMH + PAMH) + (BMH + IMH + BRCT)RTS)(OT/MTBF) \\ + ((MRF + MRO + OST + SR + TR)RTS)(OT/MTBF)] \end{aligned} \qquad (15)$$

Where [1:2-1 - 2-8]

SMH	is average manhours to perform a scheduled periodic or phased inspection on the system.
SMI	is the interval in flying hours between scheduled maintenance inspections
BCMH	is average manhours to perform a shop bench check, screening, and fault verification on a removed FLU or LRU prior to initiating repair action or condemning the item.
PAMH	is average manhours expended in place on the installed system for preparation and access for the FLU or LRU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment.
BMH	is average manhours to perform intermediate level (base shop) maintenance on a removed FLU or LRU including fault isolation, repair, and verification
IMH	is average manhours to perform corrective maintenance of the FLU or LRU in place on line without removal including fault isolation, repair and isolation

BRCT	is average base repair cycle time in months
RTS	fraction of removed FLUs/LRUs expected to be repaired at base level
MRF	average manhours per failure to complete off-equipment maintenance records
MRO	average manhours per failure to complete on-equipment maintenance records
OST	average order and shipping time in months; The elapsed time between the initiation of a request for a serviceable item and its receipt by a requesting activity
SR	average manhours per failure to complete supply transaction records
TR	average manhours per failure to complete transportation transaction forms
UR	is the peacetime utilization rate per aircraft (hrs./mo.)

This representation accounts for the time that a system is actually undergoing preventative and corrective maintenance fairly well. The average logistics delay time (ALDT) portion can be further developed, however.

From equations 14 and 15:

$$ALDT = ((MRO + MRF + OST + SR + TR)\ RTS)(OT/MTBF) \qquad (16)$$

This results in a pessimistic estimation of ALDT because of the RTS (repairable this station) factor. Intuitively, one would expect the ordering and shipping factors (OST, SR, and TR) to be associated with the NRTS (not repairable this station) actions. Further, the record keeping functions (MRO and MRF) are accomplished any time maintenance is done. This suggests the following equation for ALDT:

$$ALDT = (MRO + MRF + (OST + SR + TR)\ NRTS)(OT/MTBF) \quad (17)$$

At this point, maintenance manhours and supply delays are accounted for. Still missing are several other delaying factors that affect operational availability and lengthen system downtime. Among them are facility delays (hangar space, engine run facilities, specialized fuel system repair bays, ect) and support / test equipment delays (work stands, fuel bowsers, test sets, ect). These delay factors vary by weapon system and operational concept and are included in this data list (Appendix B) as subjective estimates only. There are other factors that could be considered, but these two are incorporated into ALDT as shown:

$$ALDT = ((MRO + MRF + (OST + SR + TR)\ NRTS) + FACDEL + SEDEL)(OT/MTBF) \quad (18)$$

where:

FACDEL	is the delay factor for required facilities

SEDEL is the delay factor for required support / test equipment

Thus the new equation for Ao is:

$$A_o = OT + ST/[OT + ST$$
$$+ ((SMH + BCMH + PAMH + BMH)(UR/SMI))$$
$$+ ((BCMH + PAMH) + (BMH + IMH + BRCT)\ RTS)(OT/MTBF)$$
$$+ ((MRF + MRO + (OST + SR + TR)\ NRTS)$$
$$+ FACDEL + SEDEL)(OT/MTBF)] \quad (19)$$

A pro   m arises in fitting this equation to CORE F. When the variable lists are compared, only RTS, BRCT, and OST are common to both CORE F and LSC.As a result, the variable list for CORE F must be expanded to include the necessary manhour and logistics delay factors. A logical place to start is with the maintenance manpower requirements equation:

$$MMP_K = \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \sum_{j=1}^{Y} \sum_{i=1}^{N_j} (MMH_i)(QPA_i)\right]$$
$$+ \left[\frac{(PAAK)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \sum_{m=1}^{M} MMH_m\right] \quad (20)$$

where [10:23]

MMP_K	is the maintenance manpower requirement for operational year, K
PAA_K	is the primary authorized aircraft per operational year, K
UR	is the peacetime utilization rate per aircraft (hrs./mo.)
MHPMP	is the total available manhours per person per month
OVHFAC	is an overhead factor applied for chief of maintenance and PMEL overhead
EFFAC	is an efficiency factor for manhours
Y	is the number of 2-digit WUCs (10 thru 99)
M	is the number of 2-digit WUCs (01 thru 09)
j	is an index identifying each 2-digit WUC
N_j	is the number of LRUs within the jth 2-digit WUC
MMH_i	is the maintenance manhours per flying hour for LRU/FLU "i"
MMH_m	is the maintenance manhours for support and general WUCs (01 - 09) for the "mth" 2-digit WUC
QPA_i	is the quantity of identical LRUs/FLUs per aircraft

The maintenance manhour factor (MMH_i) can be restated in terms of LSC manhour variables. Because MMH_i is expressed in terms of manhours per flying hour and the LSC variables are expressed in average manhours per maintenance action, the LSC variables must be converted to reflect MMH_i units:

$$MH/FH = \frac{(MH/maint.\ action)(total\ maint.\ actions)}{FH} \qquad (21)$$

Since total maintenance actions can be computed as the reciprocal of MTBM multiplied by total force flying hours, or $1/MTBM_i(TFFH_K)$, MMH_i can be restated as:

$$MMH_i = \frac{(BCMH_i + PAMH_i + BMH_i + IMH_i)(1/MTBM_i)(TFFH_K)}{(TFFH_K)} \qquad (22)$$

This simplifies to:

$$MMH_i = \frac{(BCMH_i + PAMH_i + BMH_i + IMH_i)}{MTBM_i} \qquad (23)$$

By substitution, MMP_K now becomes:

$$MMP_K = \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \sum_{j=1}^{Y} \sum_{i=1}^{N_j} \frac{BCMH_i + PAMH_i + BMH_i + IMH_i}{MTBM_i} (QPA_i)\right] + \left[\frac{(PAAK)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \sum_{m=1}^{M} MMH_m\right] \qquad (24)$$

Scheduled maintenance manhours cannot and need not be ignored. SMH, though, is a system level variable that fits outside the LRU level iterations:

$$MMP_K = \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \frac{SMH}{SMI}\right]$$

$$+ \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)}\right.$$

$$\left.\sum_{j=1}^{Y} \sum_{i=1}^{N_j} \frac{BCMH_i + PAMH_i + BMH_i + IMH_i}{MTBM_i} \quad (QPA_i)\right]$$

$$+ \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \sum_{m=1}^{M} MMH_m\right] \qquad (25)$$

where:

SMI is the interval in flying hours between scheduled maintenance inspections

Now that the LSC manhour factors have been brought into the CORE F equations, only the logistics delay factors remain. They are presented here again for clarity:

MRO manhours per failure to complete on-equipment maintenance records

MRF manhours per failure to complete off-equipment maintenance records

SR average manhours per failure to complete supply transaction records

TR average manhours to complete transportation transaction forms

Two of these, MRO and MRF, are indirect maintenance labor factors that can be incorporated into the maintenance manpower requirements equation just looked at. Assuming that most record keeping is done as maintenance actions are completed, and realizing that maintenance actions often involve more than one LRU or FLU, it follows that MRO and MRF should be added as follows:

$$
\begin{aligned}
MMP_K = {} & \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \frac{SMH}{SMI} \right] \\
& + \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \right. \\
& \quad \left[\sum_{j=1}^{Y} \frac{MRO + MRF}{MTBM_j} \right. \\
& \quad \left. \left. \sum_{j=1}^{Y} \sum_{i=1}^{N_j} \frac{BCMH_i + PAMH_i + BMH_i + IMH_i}{MTBM_i} \quad (QPA_i) \right] \right] \\
& + \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \sum_{m=1}^{M} MMH_m \right] \qquad (27)
\end{aligned}
$$

To address SR and TR, the pipeline spares equations are presented. As before:

$$PS_K = \sum_{j=1}^{Y} (F_j) \left[M_K \sum_{i=1}^{N_j} (STK_i)(UC_i) + \sum_{i=1}^{N_j} \frac{(PFFH_K)(QPA_i)(NRTS_i)(DRCT)}{(MTBD_i)} (UC_i) \right] \quad (10)$$

Recall that

$$STK_i = \lambda_i t_i + 1.6\sqrt{\lambda_i t_i} \quad (9)$$

and that

$$t_i = (RTS_i)(BRCT) + (NRTS_i)(OST)$$

where ti can also be expressed as:

$$t_i = (RTS_i)(BRCT) + NRTS_i)(OST + SR + TR) \quad (28)$$

Summary

At this point, the expanded input list for CORE F permits computation of operational availability and leads to modified equations for replenishment spares and maintenance manpower requirements. The modified CORE F outputs give operational availability data and two CORE input factors (replenishment spares and organizational / intermediate manpower). These input factors, together with CORE F output / CORE input values, can be used to derive CORE output for use in $\Delta A_o / \Delta c$ comparisons between systems.

IV. Applications Analysis

This chapter will present a simp e example of a CORE F application. The calculations involve the modified equations for maintenance manpower requirements, replenishment spares, and operational availability. The data is, for the most part, the same set that Gardner used in his modified LSC application. It comes from the HH-60D Night Hawk program and represents two alternative avionics packages, as shown in Table V, made up of radar target acquisition and electronic countermeasures subsystems.

Table V

The Alternatives

FUNCTION	WUC	PACKAGE A	PACKAGE B
TARGET ACQUISITION	74	LANTIRN	APQ-158
ECM	76	APR-39	ALR-46

All cost values (UC_i) are those that were normalized to constant year values by Gardner in his earlier effort [7:40].

The first calculations are for the replenishment spares factor (Appendix D). The initial task was to compute basstock levels (STK) for the operational year, K, (in this case year 7 is arbitrarily chosen) and for the previous year, K-1 (year 6). (See Table VI.)

Table VI

Stock Level Results

	PACKAGE A LANTIRN	PACKAGE A APR-39	PACKAGE B APQ-158	PACKAGE B ALR-46
STK_i	7	2	7	2
$STK_{i\ K-1}$	7	2	7	2

The next step is to determine the additional pipeline spares requirement for package A by computing pipeline spares cost for years 6 and 7 (PS_{K-1} and PS_K) and then subtracting the difference to get APS_K. The same is done for package B. (See Table VII.)

Table VII

Pipeline Spares Results ($/yr)

	PACKAGE A LANTIRN / APR-39	PACKAGE B APQ-158 / ALR-46
PS_K	[illegible],972,738	98,852,933
PS_{K-1}	[illegible],851,460	90,686,076
APS_K	5,121,278	8,166,857

Some limitations in the data base should be highlighted at this point. The equation for λ_i calls for mean time between demands in the denominator. MTBM, or mean time between maintenance is used instead, with the understanding that MTBD and MTBM differ in that on equipment maintenance does not necessarily generate a demand on the supply system. This in turn forces the assumption that no on-equipment maintenance is going to occur.

Another, more serious limitation is that the data set treats each system (LANTIRN, APQ-158, ect) as a single LRU. Additionally, there is no SRU data to reflect the cost of in shop spares (circuit cards and other "bits and pieces"). As a result, F_j (the SRU spares factor) is set equal to 1. Further, with each work unit code having only one LRU in the calculations, repeated iterations for multiple LRUs become unnecessary. The advantage of this is that data collection and calculations were simplified considerably and hence, did not distract from the research. The disadvantage of course, is a forced departure from the real world of multiple LRU systems and costly SRU stocks.

The next task is to calculate replenishment spares (RS_K). This means summing up pipeline spares (APS_K), condemnation spares (those that replace unserviceable or condemned spares already fielded and in the pipeline), peculiar and common support equipment spares, test equipment spares, and replacement support equipment spares. This calculation is summarized in Table VIII.

Table VIII

Replenishment Spares ($/yr)

	PACKAGE A	PACKAGE B
RS_K	130,000,000	204,010,000

In this example, $APSN_K$ and CSN_K are set equal to zero for simplicity's sake. $PSES_K$ and TES_K are also zero since they do not become active variables until year eight [8:20]. Finally, $RSFH_K$ is computed as shown in Table IX.

Table IX

Replenishment Spares/Flying Hour Results ($/fh)

	PACKAGE A	PACKAGE B
$RSFH_K$	1388	2178.16

The next series of calculations are for maintenance manpower costs (Appendix E). First, the number of maintenance people required is computed. (See Table X.)

Table X

Maintenance Manpower Results

PACKAGE A	PACKAGE B
23	20

Next, the officer, airman, civilian breakdown is computed. In each case MMP_K is multiplied by a percentage factor. Then the requirement for each category is multiplied by the average pay per year (F66 and F67 input factors in AFR 173-13) to get manpower costs. Note that at the subsystem level all manpower is enlisted ($AMXC_K$). $AMXC_K$ in terms of CORE factors is: (F71 + F74)(F67). (See Table XI.)

Table XI

Maintenance Manpower Costs ($/yr)

PACKAGE A	PACKAGE B
315.721	274,540

The next calculations are for operational availability (Appendix F). Subsystem availabilities are computed using equation 19. Treating the subsystems as a series network, where the subsystems are independent, availability is the product of the subsystem availabilities [7:80]. This result is shown in Table XII.

Table XII

Operational Availability Results

Lantirn	.47
APR-39	.89
PACKAGE A	.41
APG-158	.51
ALR-46	.91
PACKAGE B	.47

If we think carefully and extrapolate to a weapon system that is made up of numerous subsystems, trouble becomes ap arent. As more subsystem availability figures are multiplied together, the result resembles more and more a series reliability computation. The weapon system availability figure is driven to an appallingly low le el. The implication is that if we are to enjoy high system availabilities, we must have extremely high subsystem availabilities. (It should be noted that the availabilities shown in Table XII are, like the costs, relative figures meant for comparison purposes. They may well be, and hopefully are, artificially low.)

Finally, the $RSFH_K$ and $AMXC_K$ cost data are input to the CORE Model itself to calculate replenishment spares and aircraft maintenance manpower costs. For replenishment spares the algorithm from AFR 173-13 is:

(F1)(F3)(F40)

where:

F1	is the number of aircraft (PAA)
F3	is flying hours per PAA per year (FH/PAA/YR)
F40	is replenishment spares cost per flying hour (RSFH), in this case computed using the CORE F model

This algorithm, of course, calculates RS_K.

The maintenance manpower algorithms of interest are [20:108]:

(F70)(F66) + (F71)(F67)

and

(F73)(F66) + (F74)(F67)

where:

F70	is the number of officers assigned to organizational level maintenance

F66	is average officer pay
F71	is the number of enlisted personnel assigned to organizational level maintenance
F67	is average enlisted pay
F73	is the number of officers assigned to intermediate level maintenance
F74	is the number of enlisted personnel assigned to intermediate level maintenance

Since F70 and F73 equal zero in this case, the equations reduce to:

$$(F71 + F74)(F67)$$

which equals $AMXC_K$ already computed in CORE F. Hence, the summarized cost data is given in Table XIII.

Table XIII

Summary Cost/A_o Data

	PACKAGE A	PACKAGE B
replenishment spares	130,000,000	204,010,000
maintenance manpower	315,721	274,540
total cost ($/yr)	130,315,721	204,284,540
operational availability	.41	.47

<u>Summary</u>

The preceding cost/availability data forms the basis for program managers' decisions concerning design tradeoffs. With it, the PM can compare costs and availability rates and can choose either the more available subsystem or, the least costly.

V. Findings and Conclusions

The purpose of this research was twofold; to investigate the usefulness of operational availability as a surrogate for supportability, and to determine whether or not a life cycle cost model using the CAIG approved cost element structure could be modified to include operational availability as an output. In so doing, supportability could be examined together with cost as competing design configurations are evaluated.

The first research question was pursued by performing a literature review of DOD and non military documents to find support for operational availability as a supportability surrogate. That review found that operational availability is generally considered one of several terms that can represent weapon system supportability. DOD Directive 5000.39 is most clear on this interpretation. Mohr and Corner also draw direct links between supportability and availability.

The second research question involved considerably more effort. The USAF CORE model is the logical candidate for modification to include operational availability. In fact, the task is eased by working [illegible], CORE [illegible] that provides common ground [illegible], with the LSC model that was [illegible]. Expan[illegible] of CORE F's equations for replenishment spares and maintenance manpower permitted an expanded variable list to support the equation for operational availability.

Concurrent with this effort, the transform that Gardner developed for operational availability was examined and changed in two ways. The average logistics delay time segment expresses off base requisition delays differently and is expanded to include delays for facilities and support equipment in an effort to more closely approximate the operational environment.

Findings

This research led to two findings. The first followed from the literature review and validated operational availability as a surrogate for supportability.

The second finding was that the CORE model, through CORE F, can calculate operational availability in addition to cost.

Conclusions

Three conclusions arise from these findings. The first conclusion, derived from all three findings, is that CORE can aid supportability related decision making at the subsystem level. This is consistent with DOD directives which emphasize supportability along with cost, schedule, and performance.

The second conclusion follows from the first. Because CORE and CORE F use the CAIG approved cost element structures, they should be useable in support of DSARC decisions concerning both cost and supportability.

The last conclusion summarizes this research and supports Gardner's earlier effort. As he found in the case of the LSC model, a modified LCC model allows the program manager to evaluate cost and availability and take both into account in his decision making. He can seek to maximize availability subject to cost constraints or he can minimize cost and evaluate the potential impact on availability.

Recommendations

The recommendations that follow are a direct outgrowth of this research and are offered in the hope of increasing the visibility of supportability factors in future decisions.

The first recommendation is that operational availability be incorporated into CORE and CORE F as shown here. At the very least, this would force careful thought on cost and supportability issues.

Second, as Gardner and so many others have noted, equal emphasis must be placed on cost, schedule, performance, and supportability. With all its attendant difficulties, this approach is the only one that insures a weapon system that can do its job outside the laboratory.

As a last note, Gardner's proposal that availability replace supportability in DOD directives finds no real agreement here. There are several ways to measure supportability; availability is just one of them. More research needs to be done before other measures are rejected.

Areas For Future Research

Both this effort and Gardner's addressed methodology concerns. Now that CORE has been shown capable of calculating availability, it remains to future researchers to refine this methodology and apply it to more comprehensive data bases in order to validate its utility.

This research does not include any risk assessment. Future work in this area would lend considerable credence to the methodology.

Further investigation into Average Logistics Delay Time (ALDT) as defined in the Operational Availability equation (equation 19) would help demonstrate the impact of factors like FACDEL and SEDEL. Already implicit in those factors, as presented here, is the potential of facilities and support/test equipment delays to drive availability down if facilities and equipment are scarce and a queue should form.

Another approach might be to attack the fundamental weakness of logistics models in general. Logistics planning factors, some of which are imbedded in this data list, are often suspect and may or may not be accurate. The data problem is not trivial. Inaccurate planning factors in World War II contributed to shortages in POL, ammunition, cold weather gear, and other essentials in the European Theater in the late summer and fall of 1944. This, together with other logistics difficulties, led to an allied halt just short of the German frontier in September [18:16]. B.H. Liddel Hart comments on this failure to keep moving in his History of the Second World War:

> The price that the Allied Armies paid for the missed opportunity in early September was very heavy. Out of three quarters of a million casualties which they suffered in liberating Western Europe, half a million were after their September check. The cost to the world was much worse--millions of men and women died by military action and in the concentration camps of the Germans with the extension of the war. Moreover, in the longer term, in September the Russian tide had not yet penetrated into Central Europe [13:561].

Logistics planning factors were investigated in a recent Air Force Logistics Management Center report which found that today's planning factors are perhaps no better than they were in World War II [6:2].

These factors cover a broad spectrum of logistics planning and decision making of which cost analysis is only a part. The implications of inaccurate planning factors are sobering.

Future research might examine selected factors in an attempt to verify their accuracy.

APPENDIX A: Variable List

ALDT	is average logistics delay time
APS_K	is the additional (delta) pipeline spares cost needed to support the increased number of aircraft and the increased flying hour program associated with weapon system phase-in
$APSN_K$	is the additional pipeline spares cost (APSk) for non-stock listed "N" items
$APSS_K$	is the additional pipeline spares cost (APSk) for stock listed "S" items
BCMH	is average manhours to perform a shop bench check, screening, and fault verification on a removed FLU or LRU prior to initiating repair action or condemning the item.
BMH	is average manhours to perform intermediate level (base shop) maintenance on a removed FLU or LRU including fault isolation, repair, and verification
BRCT	is the standard base repair cycle time in months
$CSES_K$	is the annual cost for common support equipment spares
CSN_K	is the annual condemnation spares cost for non-stock listed "N" items
CSS_K	is the annual condemnation spares cost for stock listed "S" items
DRCT	is the standard depot repair cycle time in months
EFFAC	is an efficiency factor for manhours
FACDEL	is the delay factor for required facilities

F_j	is the factor used to calculate SRU (shop replaceable unit) pipeline spares dollar requirements for the jth 2-digit WUC
i	is the index identifying each LRU
IMH	is average manhours to perform corrective maintenance of the FLU or LRU in place on line without removal including fault isolation, repair and isolation
j	is an index identifying each 2-digit WUC
m	is the number of 2-digit WUCs (01 thru 09)
MHPMP	is the total available manhours per person per month
M_K	is the number of active bases for each operational year, K
MMH_i	is the maintenance manhours per flying hour for LRU/FLU "i"
MMH_m	is the maintenance manhours for support and general WUCs (01 - 09) for the "mth" 2-digit WUC
MMP_K	is the maintenance manpower requirement for operational year, K
MRF	average manhours per failure to complete off-equipment maintenance records
MRO	average manhours per failure to complete on-equipment maintenance records
$MTBD_i$	is the mean time between demands in flying hours for the ith LRU
N_j	is the number of individual LRUs within the jth 2-digit work unit code (WUC)
$NRTS_i$	is the fraction of the ith LRU removals not reparable at base level
OST	is the standard order and shipping time in months

OT	is operational time
OVHFAC	is an overhead factor applied for chief of maintenance and PMEL overhead
PAA_K	is the primary authorized aircraft per operational year, K
PAMH	is average manhours expended in place on the installed system for preparation and access for the FLU or LRU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment.
$PFFH_K$	is peak monthly force flying hours in operational year, K
PS_K	is total cumulative pipeline spares cost per operational year, K
$PSES_K$	is the annual cost of peculiar support equipment spares
QPA_i	is the quantity of identical LRUs/FLUs per aircraft
$RPLSES_K$	is the annual cost for replacement support equipment spares
RTS_i	fraction of removed ith FLUs/LRUs expected to be repaired at base level
SEDEL	is the delay factor for required support / test equipment
SMH	is average manhours to perform a scheduled periodic or phased inspection on the system.
SMI	is the interval in flying hours between scheduled maintenance inspections
SR	average manhours per failure to complete supply transaction records
ST	is standby time
TCM	is total corrective maintenance time

TES_K	is the annual cost for training equipment spares
$TFFH_K$	is the total force flying hours per operational year, K, for all delivered aircraft
TPM	is total preventative maintenance time
TR	average manhours per failure to complete transportation transaction forms
UC_i	is the cumulative average unit production cost for the ith LRU
UR	is the peacetime utilization rate per aircraft (hrs./mo.)
Y	is the number of 2-digit WUCs (10 thru 99)

CORE Variables

F1	is the number of aircraft (PAA)
F3	is flying hours per PAA per year (FH/PAA/YR)
F40	is replenishment spares cost per flying hour (RSFH), in this case computed using
F70	is the number of officers assigned to organizational level maintenance
F66	is average officer pay
F71	is the number of enlisted personnel assigned to organizational level maintenance
F67	is average enlisted pay
F73	is the number of officers assigned to intermediate level maintenance
F74	is the number of enlisted personnel assigned to intermediate level

APPENDIX B: Input Values

PACKAGE A

VARIABLE NAME	LANTIRN	APR-39
PAA_K	201	201
UR	38.8 hrs/mo	38.8 hrs/mo
OVHFAC	1.120	1.120
MHPMP	145.200	145.200
EFFAC	0.600	0.600
SMH	0	0
SMI	0	0
MRO	.08 hr	.08 hr
MRF	.24 hr	.24 hr
$MTBM_j$	----	----
$BCMH_i$	1.3 hr	.4 hr
$PAMH_i$	.087 hr	.07833 hr
BMH_i	2.6 hr	1.2 hr
IMH_i	1.6255 hr	2.7 hr
$MTBM_i$	29 hrs	249 hrs
QPA_i	1	1
MMH_m	0	0
F_j	----	----
M_K	24 (yr 7)	24 (yr 7)
	22 (yr 6)	22 (yr 6)

UC_i *	163,482.65	7473.49
$PFFH_K$	7920 hrs (yr 7)	7920 hrs (yr 7)
	7270 hrs (yr 6)	7270 hrs (yr 6)
$NRTS_i$	.27	.05
DRCT	2.83 mo	2.83 mo
$MTBD_i$	---	---
RTS_i	.70	.92
BRCT	.33 mo	.33 mo
OST	.394 mo	.394 mo
SR	.0003472 mo	.0003472 mo
TR	.0002222 mo	.0002222 mo
OT	80 hrs	80 hrs
ST	526 hrs	526 hrs
FACDEL **	3.0 hrs	3.0 hrs
SEDEL **	1.0 hrs	1.0 hrs
TFFH	93,660	93,660
$COND_i$	.12857	.51
F_K	---	---

PACKAGE B

VARIABLE NAME	APQ-158	ALR-46
PAA_K	201	201
UR	38.8 hrs/mo	38.8 hrs/mo
OVHFAC	1.120	1.120
MHPMP	145.200	145.200
EFFAC	0.600	0.600
SMH	0	0
SMI	0	0
MRO	.08 hr	.08 hr
MRF	.24 hr	.24 hr
$MTBM_j$	---	---
$BCMH_i$	2.3 hr	.9 hr
$PAMH_i$	.8 hr	.5 hr
BMH_i	1.6 hr	1.5 hr
IMH_i	1.4 hr	.85 hr
$MTBM_i$	35 hrs	325 hrs
QPA_i	1	1
MMH_m	0	0
F_j	---	---
M_K	24 (yr 7)	24 (yr 7)
	22 (yr 6)	22 (yr 6)

UC_i *	249,771	15,575.21
$PFFH_K$	7920 hrs (yr 7)	7920 hrs (yr 7)
	7270 hrs (yr 6)	7270 hrs (yr 6)
$NRTS_i$	.35	.15
DRCT	2.83 mo	2.83 mo
$MTBD_i$	----	----
RTS_i	.60	.80
BRCT	.33 mo	.33 mo
OST	.394 mo	.394 mo
SR	.0003472 mo	.0003472 mo
TR	.0002222 mo	.0002222 mo
OT	80 hrs	80 hrs
ST	526 hrs	526 hrs
FACDEL **	3.0 hrs	3.0 hrs
SEDEL **	1.0 hrs	1.0 hrs
TFFH	93,660 hrs	93,660 hrs
$COND_i$	.16	.40
F_K	----	----

* Normalized cost data (UC_i) from An Examination of Operational Availability in Life Cycle Cost Models [7:69]

** Subjective Estimates

All other data is from Appendix B, An Examination of Operational Availability in Life Cycle Cost Models [7:63], and IBM Report 83-LCC-2A [8].

APPENDIX C: Equation List

Equations 7 and 28: Mean Demand Rate per Base

$$\lambda_i = \frac{(PFFH_K)(QPA_i)}{(M_K)(MTBD_i)} \qquad (7)$$

$$t_i = (RTS_i)(BRCT) + NRTS_i)(OST + SR + TR) \qquad (28)$$

Equation 9: Spares Stockage Level For LRU i (Includes Safety Stock)

$$STK_i = \lambda_i t_i + 1.6\sqrt{\lambda_i t_i} \qquad (9)$$

Equation 10: Pipeline Spares

$$PS_K = \sum_{j=1}^{Y} (F_j) \left[M_K \sum_{i=1}^{N_j} (STK_i)(UC_i) + \sum_{i=1}^{N_j} \frac{(PFFH_K)(QPA_i)(NRTS_i)(DRCT)}{(MTBD_i)} (UC_i) \right] \qquad (10)$$

Equation 11: The Increment Increase in Pipeline Spares for Operational Year, K

$$\Delta PS_K = PS_K - (PS_{K-1}) \qquad (11)$$

Equation 12: Replenishment Spares per Operational Year

$$RS_K = \sum_{k=1}^{H+1} APSS_K + \sum_{k=3}^{H+1} APSN_K + \sum_{k=1}^{K} CSS_K + \sum_{k=3}^{K} CSN_K + \sum_{k=H+1}^{K} PSES_K$$
$$+ \sum_{k=1}^{K} CSES_K + \sum_{k=H+1}^{H} TES_K + \sum_{k=1}^{K} RPLSES_K \qquad (12)$$

Equation 13: Replenishment Spares per Flying Hour

$$RSFH_K = \frac{RS_K}{TFFH_K} \qquad (13)$$

Equation 4: Operational Availability

$$A_O = \frac{OT+ST}{OT+ST+TPM+TCM+ALDT} \qquad (4)$$

Equation 19: The Expanded Version of Operational Availability

$$A_O = OT + ST/[OT + ST$$
$$+ ((SMH + BCMH + PAMH + BMH)(UR/SMI))$$
$$+ ((BCMH + PAMH) + (BMH + IMH + BRCT)RTS)(OT/MTBF)$$
$$+ ((MRF + MRO + OST + SR + TR)RTS)(OT/MTBF)$$
$$+ FACDEL + SEDEL] \qquad (19)$$

Equation 27: Maintenance Manpower for Operational Year, K

$$MMP_K = \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \frac{SMH}{SMI} \right]$$

$$+ \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \right.$$

$$\left[\sum_{j=1}^{Y} \frac{MRO + MRF}{MTBM_j} \right.$$

$$\left. \left. + \sum_{j=1}^{Y} \sum_{i=1}^{N_j} \frac{BCMH_i + PAMH_i + BMH_i + IMH_i}{MTBM_i} (QPA_i) \right] \right]$$

$$+ \left[\frac{(PAA_K)(UR)(OVHFAC)}{(MHPMP)(EFFAC)} \quad \sum_{m=1}^{M} MMH_m \right] \qquad (27)$$

APPENDIX D: Calculations For Replenishment Spares

PACKAGE A:

Lantirn:

$$t_i = (.70)(.33) + (.27)(.394 + .0003472 + .0002222)$$

$$= .231 + .1065337$$

$$= .3375337$$

$$\lambda_i = \frac{(7920)(1)}{(24)(29)} = 11.37931$$

$$STK_i = (11.37931)(.3375337)$$

$$+ 1.6 \sqrt{(11.37931)(.3375337)}$$

$$= 3.8409007 + 3.1357146$$

$$= 6.9766153$$

which rounds to:

$$STK_i = 7$$

$$\lambda_{i\ k-1} = \frac{(7270)(1)}{(22)(29)} = 11.394984$$

$$STK_{i\ k-1} = (11.394984)(.3375337)$$

$$+ 1.6 \sqrt{(11.394984)(.3375337)}$$

$$= 3.8461912 + 3.1378734$$

$$= 6.9840646$$

which rounds to:

$$STK_{i\ k-1} = 7$$

APR-39:

$$t_i = (.92)(.33) + (.05)(.394 + .0003472 + .0002222)$$

$$= .3036 + .0197285$$

$$= .3233285$$

$$\lambda_i = \frac{(7920)(1)}{(24)(249)} = 1.3253012$$

$$STK_i = (1.3253012)(.3233285)$$

$$+ 1.6\sqrt{(1.3253012)(.3233285)}$$

$$= .4285076 + 1.0473679$$

$$= 1.4758756$$

which rounds to:

$$STK_i = 2$$

$$\lambda_{i\ k-1} = \frac{(7270)(1)}{(22)(249)} = 1.3271267$$

$$STK_{i\ k-1} = (1.3271267)(.3233285)$$

$$+ 1.6\sqrt{(1.3271267)(.3233285)}$$

$$= .4290979 + 1.048089$$

$$= 1.4771869$$

which rounds to:

$$STK_{i\ k-1} = 2$$

$$PS_K = 1\left[\left[(24)(7)(163{,}482.65) + (24)(2)(7{,}473.49)\right] + \left[\frac{(7920)(1)(.27)(2.83)}{(29)}(163{,}482.65) + \frac{(7920)(1)(.05)(2.83)}{(249)}(7{,}473.49)\right]\right]$$

$$= 61{,}972{,}738$$

$$PS_{K-1} = 1\left[\left[(22)(7)(163{,}482.65) + (22)(2)(7{,}473.49)\right] + \left[\frac{(7270)(1)(.27)(2.83)}{(29)}(163{,}482.65) + \frac{(7270)(1)(.05)(2.83)}{(249)}(7{,}473.49)\right]\right]$$

$$= 56{,}851{,}460$$

$$APS_K = 61{,}972{,}738 - 56{,}851{,}460$$

$$= 5{,}121{,}278$$

$$RS_K = \sum_{k=1}^{H+1} APSS_K + \sum_{k=3}^{H+1} APSN_K + \sum_{k=1}^{K} CSS_K + \sum_{k=3}^{K} CSN_K + \sum_{k=H+1}^{K} PSES_K$$

$$+ \sum_{k=1}^{K} CSES_K + \sum_{k=H+1}^{H} TES_K + \sum_{k=1}^{K} RPLSES_K$$

where

$\sum_{k=1}^{n}$ is a notation that identifies for each year, K, the cost elements that are to be added.

H is the last year of production.

K is the end of operational life.

1 is the first year of deployment.

k index for operational year.

$APSS_K = APS_K = 5,121,278$

$APSN_K = 0$

$CSS_K = CS_K$

$$= \sum_{j=1}^{Y} \sum_{i=1}^{N_j} \frac{(TFFH_K)(QPA_i)(COND_i + CDNP_i)(UC_i)(F_K)}{(MTBD_i)}$$

$$= \frac{(93,660)(1)(.12857)(163,482.65)(1.8)}{(29)}$$

$$+ \frac{(93,660)(1)(.51)(7473.49)(1.8)}{(249)}$$

$$= 124,770,000$$

$CSN_K = 0$ (Both $APSN_K$ and CSN_K are set at zero to simplify calculations.)

$PSES_K = 0$ ($PSES_K$ becomes active in year 8.)

$CSES_K = CCSE_K\ (CSEFAC_K) = 2.681(.04) = .10724$ mil

$= 107,240$

$RPLSES_K = RPLSE_K\ (RPLFAC) = .113(.042) = .004746$ mil

$= 4,746$

$RS_K = (\ \ 21,278) + (0) + (124,770,000) + (0) + (0)$

$+ (107,240) + (0) + (4,746)$

$= 130,000,000$

$RSFH_K = RS_K/TFFH = 130,000,000/93,660 = \$1388/FH$

PACKAGE B:

APQ-158:

$$t_i = (.60)(.33) + (.35)(.394 + .0003472 + .0002222)$$

$$= .198 + .1380993$$

$$= .3360993$$

$$\lambda_i = \frac{(7920)(1)}{(24)(35)} = 9.4285714$$

$$STK_i = (9.4285714)(.3360993)$$

$$+ 1.6 \sqrt{(9.4285714)(.3360993)}$$

$$= 3.1689363 + 2.848241$$

$$= 6.0171773$$

which rounds to:

$$STK_i = 7$$

$$\lambda_{i\ k-1} = \frac{(7270)(1)}{(22)(35)} = 9.4415584$$

$$STK_{i\ k-1} = (9.4415584)(.3360993)$$

$$+ 1.6 \sqrt{(9.4415584)(.3360993)}$$

$$= 3.1733012 + 2.8502019$$

$$= 6.0235031$$

which rounds to:

$$STK_{i\ k-1} = 7$$

ALR-46:

$$t_i = (.80)(.33) + (.15)(.394 + .0003472 + .0002222)$$

$$= .264 + .0591854$$

$$= .3231854$$

$$\lambda_i = \frac{(7720)(1)}{(24)(3.\ \ )} = 1.0153846$$

$$STK_i = (1.0153846)(.3231854)$$

$$+ 1.6\sqrt{(1.0153846)(.3231854)}$$

$$= .3281575 + .9165605$$

$$= 1.244718$$

which rounds to:

$$STK_i = 2$$

$$\lambda_{i\ k-1} = \frac{(7270)(1)}{(22)(325)} = 1.0167832$$

$$STK_{i\ k-1} = (1.0167832)(.3231854)$$

$$+ 1.6\sqrt{(1.0167832)(.3231854)}$$

$$= .3286095 + .9171915$$

$$= 1.245801$$

which rounds to:

$$STK_{i\ k-1} = 2$$

$$
\begin{aligned}
PS_K = 1\Bigg[\Big[&(24)(7)(249{,}771) \\
&+ (24)(2)(15{,}575.21)\Big] \\
&+ \Big[\frac{(7920)(1)(.35)(2.83)}{(35)}(249{,}771) \\
&+ \frac{(7920)(1)(.15)(2.83)}{(325)}(15{,}575.21)\Big]\Bigg] \\
&= 98{,}852{,}933
\end{aligned}
$$

$$
\begin{aligned}
PS_{K-1} = 1\Bigg[\Big[&(22)(7)(249{,}771) \\
&+ (22)(2)(15{,}575.21)\Big] \\
&+ \Big[\frac{(7270)(1)(.35)(2.83)}{(35)}(249{,}771) \\
&+ \frac{(7270)(1)(.15)(2.83)}{(325)}(15{,}575.21)\Big]\Bigg] \\
&= 90{,}686{,}076
\end{aligned}
$$

$$
\begin{aligned}
APS_K &= 98{,}852{,}933 - 90{,}686{,}076 \\
&= 8{,}166{,}857
\end{aligned}
$$

$$CS_K = \frac{(93,660)(1)(.16)(249,771)(1.8)}{(35)}$$

$$+ \frac{(93,660)(1)(.40)(15,575.21)(1.8)}{(325)}$$

$$= 195,730,000$$

$$RS_K = (8,166,857) + (0) + (195,730,000) + (0)$$

$$+ (0) + (107,240) + (0) + (4,746)$$

$$= 204,010,000$$

$$RSFH_K = 204,010,000/93,660 = \$2178.16/FH$$

APPENDIX E: <u>Calculations For Maintenance Manpower Requirements</u>

<u>PACKAGE A:</u>

Lantirn / APR-39:

$$
\begin{aligned}
MMP_K = & \left[\frac{(201)(38.8)(1.120)}{(145.200)(0.60)} \quad (0) \right] \\
& + \left[\frac{(201)(38.8)(1.120)}{(145.200)(0.60)} \right. \\
& \quad \left[\left[\frac{.08 + .24}{(29)} \quad + \quad \frac{.08 + .24}{(249)} \right] \right. \\
& + \left[\frac{(1.3) + (.087) + (2.6) + (1.6255)}{(29)} (1) \right. \\
& \left. \left. \left. + \quad \frac{(.4) + (.07833) + (1.2) + (2.7)}{(249)} (1) \right] \right] \right] \\
& + \left[\frac{(201)(38.8)(1.120)}{(145.200)(.60)} \quad (0) \right] \\
= & \ (100.26006) \left[(.0123196) + (.1935345) + (.0175837) \right] \\
= & \ (100.26006)(.2234378) \\
= & \ 22.401887
\end{aligned}
$$

which rounds to:

$$MMP_K = 23$$

$$OFFXC_K = (OFFFAC)(MMP_K) = (.02)(23) = .46$$

$$AMXC_K = (AMNFAC)(MMP_K = (.98)(23) = 22.54$$

$$CMXC_K = (CIVFAC)(MMP_K) = (0)(23) = 0$$

$$MMC_K = (OFFXC_K)(OFFPYR) + (AMXC)(AMNPYR)$$

$$+ (CMXC)(CIVPYR)$$

$$= (0) + (23)(13727) + (0)$$

$$= 315,721$$

Note that the officer fraction is rounded down to 0. If we were running computations for all HH-60 avionics we would expect to see a number greater than 1 to account for officer manning at branch level (ie an avionics maintenance branch in an intermediate level maintenance squadron). In such a case we would not round down.

PACKAGE B:

APQ-158 / ALR-46:

$$MMP_K = \left[\frac{(201)(38.8)(1.120)}{(145.200)(0.60)} \quad (0)\right]$$

$$+ \left[\frac{(201)(38.8)(1.120)}{(145.200)(0.60)}\right]$$

$$\left[\left[\frac{.08 + .24}{(35)} + \frac{.08 + .24}{(325)}\right]\right.$$

$$\left[\frac{(2.3) + (.8) + (1.6) + (1.4)}{(35)}(1)\right.$$

$$\left.\left. + \frac{(.9) + (.5) + (1.5) + (.85)}{(325)}(1)\right]\right]$$

$$+ \left[\frac{(201)(38.8)(1.120)}{(145.200)(.60)} \quad (0)\right]$$

$$= (100.26006)\left[(.0101275) + (.1742857) + (.0115385)\right]$$

$$= (100.26006)(.1959517)$$

$$= 19.646125$$

which rounds to:

$$MMP_K = 20$$

$$OFFXC_K = (.02)(20) = .40$$

$$AMXC_K = (.98)(20) = 19.6$$

$$CMXC_K = (0)(20) = 0$$

$$MMC_K = 0 + (20)(13727) + 0$$

$$= 274,540$$

$AMXC_K$ corresponds to factors F71, F74, and F67 of the USAF CORE Model given in AFR 173-13. The relationship is:

$$AMXC_K = (F71 + F74)(F67)$$

where:

F71		is organizational enlisted manpower
F74		is intermediate enlisted manpower
F67		enlisted pay

APPENDIX F: Calculations For Operational Availability

PACKAGE A:

Lantirn:

$$A_o = (80 + 526)/(80 + 526) + \Big[(0 + 1.3 + .087 + 2.6)0\Big]$$

$$+ \Big[(1.3 + .087) + (2.6 + 1.6255 + 237.6).70\Big] \; (80/29)$$

$$+ \Big[\Big[(.24 + .08) + (.25 + .16 + 283.68).27\Big]$$

$$+ 3.0 + 1.0\Big] \; (80/29)$$

$$= \frac{606}{606 + 0 + 470.79959 + 223.51531}$$

$$= \frac{606}{1300.3149}$$

$$= .466041$$

APR--39:

$$A_o = (80 + 526)/(80 + 526) + \Big[(0 + 0.4 + .07833 + 1.2)0\Big]$$

$$+ \Big[(.4 + .07833) + (1.2 + 2.7 + 237.6).92\Big] \; (80/249)$$

$$+ \Big[\Big[(.24 + .08) + (.25 + .16 + 283.68).05\Big]$$

$$+ 3.0 + 1.0\Big] \; (80/249)$$

$$= \frac{606}{606 + 0 + 71.536813 + 5.9516466}$$

$$= \frac{606}{683.48846}$$

$$= .886628$$

PACKAGE B:

APQ-158:

$$A_o = (80 + 526)/(80 + 526) + \left[(0 + 2.3 + .8 + 1.6)0\right]$$
$$+ \left[(2.3 + .8) + (1.6 + 1.4 + 237.6).60\right] (80/35)$$
$$+ \left[\left[(.24 + .08) + (.25 + .16 + 283.68).35\right]\right.$$
$$\left. + 3.0 + 1.0\right] (80/35)$$
$$= \frac{606}{606 + 0 + 337.05143 + 237.14629}$$
$$= \frac{606}{1180.1977}$$
$$= .5134733$$

ALR-46:

$$A_o = (80 + 526)/(80 + 526) + \left[(0 + .9 + .5 + 1.5)0\right]$$
$$+ \left[(.9 + .5) + (1.5 + 85 + 237.6).80\right] (80/325)$$
$$+ \left[\left[(.24 + .08) + (.25 + .1 + 283.68).15\right]\right.$$
$$\left. + 3.0 + 1.0\right] (80/325)$$
$$= \frac{606}{606 + 0 + 47.596308 + 11.552862}$$
$$= \frac{606}{665.14917}$$
$$= .9110738$$

Again, treating the availabilities of two subsystems are independent events, the package availabilities are calculated as products of the subsystem availabilities.

PACKAGE A:

(.466041) .886628) = .413205

PACKABE B:

(.5134733)(.9110738) = .4678121

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VITA

Captain Fredrick C. Farnell was born on 30 October 1954 in San Bernardino, California. He graduated from high school in Littleton, Colorado in 1972. In 1974, he entered the United States Air Force Academy from which he received the degree of Bachelor of Science in History (with emphasis on Soviet Area Studies). Following graduation and commissioning in June 1978, he completed pilot training and received his wings in November 1979. He served as a T-37 instructor pilot in the 85th Flying Training Squadron, Laughlin AFB, Texas until a medical grounding in September 1980. After serving briefly as Wing Mobility Officer at Laughlin, Captain Farnell went to the 37th Tactical Fighter Wing at George AFB, California in January 1981 where he served as an F-4E/F-4G Maintenance Officer. He held a variety of positions there, including Officer in Charge, 561st Aircraft Maintenance Unit and 37th TFW Maintenance Control Officer. He entered the School of Systems and Logistics, Air Force Institute of Technology, in June 1983.

Permanent address: 409 McKinley St SE
Salem, Oregon 97302

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In recent years, interest in weapon system supportability has grown tremendously. Coupled with this is a complementary emphasis on life cycle cost analysis. Both arise from a concern that weapon system ownership costs are extraordinarily high and that improved understanding of supportability issues and their effect on life cycle costs can result not only in dollar savings, but in increased system readiness and capability. These considerations led to development of a methodology for comparing ownership costs and supportability that enables Program Managers to more easily evaluate design tradeoffs. The methodology involves use of a modified life cycle cost model that yields as outputs both relative cost and supportability, where operational availability acts as a measurable surrogate for supportability. The modified model uses the DOD's CAIG approved cost element structures for aircraft in an attempt to use cost/availability output in support of Defense Acquisition Review Council (DSARC) milestones. The methodology is applied to a sample data base from the HH-60D program.